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THESIS

DECISION SUPPORT SYSTEMS
FOR THE COMMERCIAL AVIATION INDUSTRY

by

Edward Y. H. Chow

December 1981

Thesis Advisor: R.H. Weissinger-Baylon

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Approved for Public Release; Distribution Unlimited

Decision Support Systems for the Commercial Aviation Industry

by

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Lieutenant, United States Navy
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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN INFORMATION SYSTEMS

from the

NAVAL POSTGRADUATE SCHOOL
December 1981

ABSTRACT

This thesis is a case study of incidents involved in commercial aviation communication errors. The case studies were compiled by NASA's Aviation Safety Reporting System (ASRS). Human error due to: retroactive interference (prior input), reductive coding (multiple input), psychological refractory phase (misinterpreted input), inferential shortcomings (assumption) and the role leadership and crew coordination play are elements of cause portrayed in these case studies. The application of a decision support system into the cockpit environment will be presented by using descriptions of support systems currently being implemented on Boeing's new 757 and 767 jet airliners. Forecasts of future DSS research and development will also be discussed.

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I. INTRODUCTION

A recent study was conducted by NASA Aviation Safety Reporting System of incidents in commercial aviation. During this investigation it was discovered that an inordinate number of errors were due to interpersonal and personal communication failure. In the subsequent pages of this thesis, twenty-two of these case studies will be scrutinized in order to underline the need for a viable application of decision support system (DSS) in the cockpit environment.

The case studies are broken into five categories. Each incident will have the narrative leading into the study. For additional reference, the twenty-two case studies (in their original format) are available in Appendix A of this thesis.

The five classified categories include:

1. Retroactive Interference - The action of the individual is not identified with the problem at hand. This is motivated by an assimilation of prior input into an on-going program.
2. Reductive Coding - An overload of input or a complex stages of events, prohibits the human unit from correctly handling the situation.
3. Psychological Refractory Phase - The human unit receives the input. However, a simultaneous transference of this information does not occur. There is a segment

of time between the input and output, leaving a window open to information loss or personal interpolation of an event or incoming data.

4. Inferential Shortcomings - Application of "knowledge structures" and "heuristics" to a situation for supposition of data which is non-existent. In short, human error due to assumption.

5. Leadership and Crew Coordination - Protocol and the social hierarchy of the aircraft are examined in reference to their role in the cockpit environment.

The action/interaction of these five sections with regard to the decisionmaking process is illustrated in Figure 1. A single element or a combination of these elements could invoke an error, as is revealed in the case studies.

The application of a DSS into the cockpit environment will be presented as a tool to help alleviate some of the workload pilots and co-pilots experience. This support could lead to a reduction of errors. Emphasis is placed on the fact that the human unit may continue to make errors. Only through each crew member's realization that such reality is plausible can a reduction of the human type error occur.

A description of "state of the art" equipment and technology in use on Boeings 757 and 767 airlines gives the reader a perception of the onboard application of a DSS. Future possibilities in research and development are also discussed. These plans could even further support the crew,

eliminating more of the crew's workload and perhaps someday possibly eliminating the necessity of the crew itself.

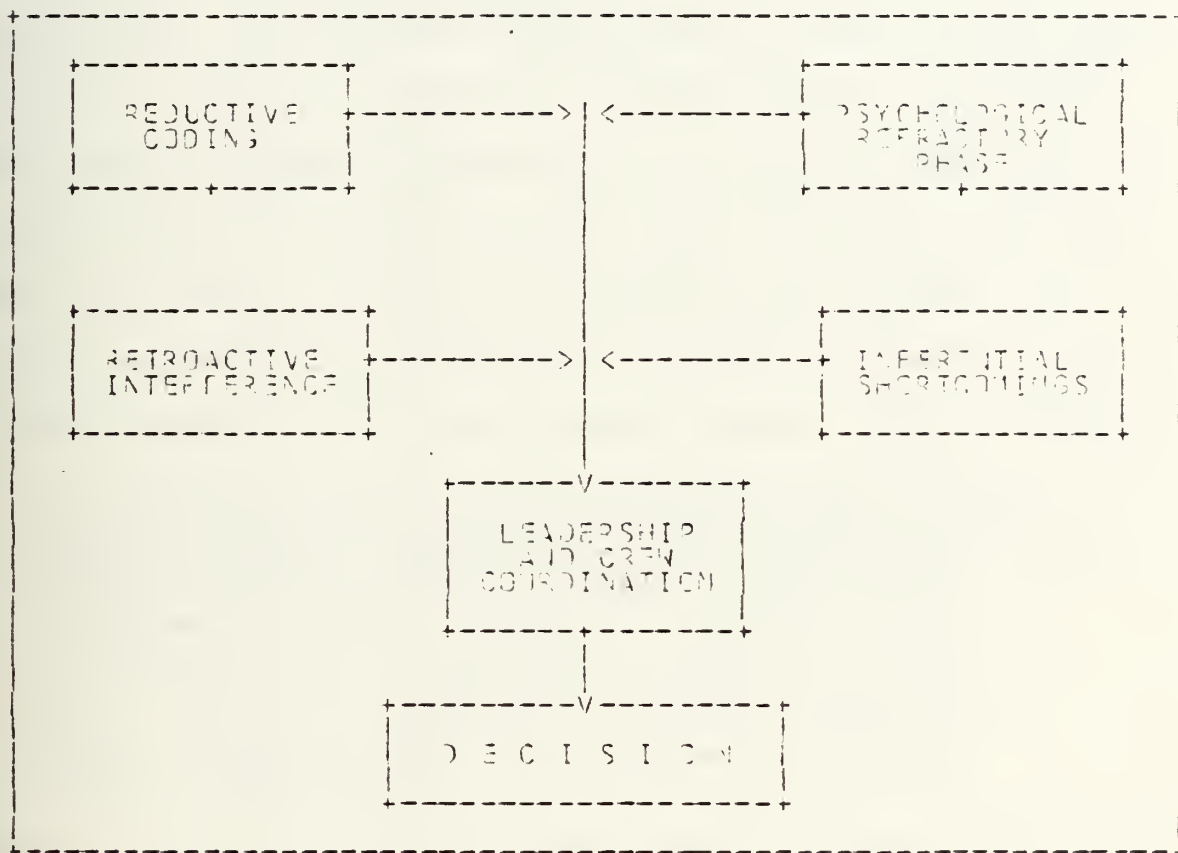


Figure 1: Model of Action/Interaction

II. CASE STUDY ANALYSIS

A. RETROACTIVE INTERFERENCE

The first error related segment to be discussed lies in the area of retroactive interference, which is also called prior input. The concept of retroactive interference implies that prior input or previously learned behavior interferes with ongoing programs [Reference 1: pp. 100]. When the action of the individual does not meet the present requirement or situation, in fact is triggered from similar previously experienced circumstance or habitual response, one is dealing with prior input. Reason defines this by stating:

"The performance of a highly practised and largely automated job liberates the control procession from moment-to-moment control; but since like nature, focal attention abhors a vacuum, it tends to be "captured" by some pressing but parallel mental activity so that on occasion it fails to switch back to the task at hand at a critical decision point and thus permits the guidance of action to fall by default under the strong motor program."
[Ref. 2: pp. 85]

These "slips of action" can occur during routine flights which demand unroutine maneuvers or during times of stress or emergency station. There are two cases in Appendix A which exhibit examples of the aforementioned "slips of action".

1. Case Study 2117

Case Study 2117 states that during a flight originating in Hot Springs, Arkansas, a clearance from the tower

was "... V-54N maintain 5000, contact Little Rock approach control at Benton intersection ...". The first officer read the clearance back to tower as issued. However, the flight misread the clearance and proceeded as cleared and (and as filed) to 7000 ft. instead of 5000 ft. (7000 ft. is fal center stored flight plan.) The reason for this deviation from the control tower's instruction is explained in the call back comment.

Narrative of Case 2117: Prior to departure from Hot Springs (Hot), Arkansas, airline flight received IFR clearance for Hot Tower, ... V-54 maintain 5000, contact Little Rock (Lit) approach control at Benton intersection ... First officer read clearance back to tower as issued. Flight crew misread clearance and proceed as cleared (and as filed) to 7000 instead of 5000. (7000 is fal center stored flight plan). The error was not discovered until flight reported over Benton intersection. If an altitude verification had been required prior to Benton intersection, the incident could have been avoided. As it was, however, flight flew one half of the flight segment without being required to verify the assigned altitude of 5000. Flight monitored Hot Tower frequency until Benton intersection.

Case study 2117 is an example of what can happen when there is a change from S.O.P. Although the first officer received the altered altitude of 5000 ft., the crew had been so accustomed to flying the center stored altitude of 7000 ft. that the change did not register mentally. A confusion existed between ongoing and stored mental programs. Since there was no emergency or crises situation which might elicit an error from stress, the crew presumably accepted the error as the proper altitude without hesitation because of the familiarity.

2. Case Study 3272

Another incident involving reversal to a previous response arose in Case Study 3272.

Narrative of Case Study 3272: On take-off we were told to turn right on top 7000 ft. I started to turn right and co-pilot said no he read back left turn. Because for years we have turned left on this take-off I took the co-pilot word instead of clarifying with departure control. Departure control stopped my turn at 270 degrees and advised me the landings were on Rwy 8 and we were turning into traffic. We did not come close to any other aircraft and he climbed us up our landing traffic and continued left turn to our course.

The pilot received instructions to turn right when he reached 7000 ft. When he proceeded to execute the maneuvers, the co-pilot informed him that he had read turn left. Since for years they had always turned left, he allowed the co-pilot to convince him that a left turn was the correct direction and turned left. Naturally, the tower informed him he was in error and was in fact turning into the traffic. Whether or not the co-pilot heard the tower say "left" instead of "right" in his mind was not expressed, but it is highly likely that due to the previous input of always turning left he did indeed mentally register left while he heard right. There again was no on-going emergency during the procedure which might force the mind to error, but none of the cases presented by NASA in this series projected extreme emergencies or life threatening events. The errors made were usually under normal or semi-stressful conditions. Both of the cases discussed could have led to serious consequences had traffic been at the appropriate altitude when the errors were committed. It is

difficult to guard against occurrences such as these as long as the human element is the ultimate controller of the cockpit environment. The tendency to regress to a more familiar method in dealing with semi-routine actions is overwhelming. There exists a natural bias toward prior input. The more similar the situation, the more likely one is tended toward behavior or action of a familiar pattern.

B. REDUCTIVE CODING

A ubiquitous role for human beings, and one in which some characteristic biases occur, is the coding of a complex input into a two category or few category output, perhaps in the form of a polar decision, as approach-retreat, stop-go, on-off, etc. [Ref. 3: pp. 353]. Campbell terms this multiple input overflow "reductive coding". When several elements of information/actions are occurring simultaneously, proficiency in all direction is not easily achieved. Norman-Shallice states that:

"To permit simultaneous action of cooperative acts and prevent simultaneous action of conflicting ones is a difficult job, for often the details of how the particular actions are performed determine whether or not they conflict with one another." [Ref. 4: pp. 13].

Contention scheduling is performed to determine exactly which amount of attention can be levied to various inputs and actions. If the simultaneous tasks are similar in nature and need of performance, it is more likely that the duplicity will qualify success in completion. However, the greater the variety or the lack of experience, the greater the tendency for an error exists.

1. Case Study 2505

There are several examples of error due to multiple input in these case studies. In Case Number 2505 the pilot was receiving a descent clearance when a flight attendant entered the cockpit to inquire about close connections for passengers upon arrival (the plane was an hour late due to mechanical difficulties).

Narrative of Case Study 2505: Enroute from SHV to DFW., cruising altitude, 16000 ft. - on the scurry four arrival (STAR), into DFW, we were given a descent to 6000 ft. in the area of Gladd intersection we were slowing at 10000 and the controller asked us our altitude. I replied 10000 (the first officer was flying the aircraft). The controller replied - climb and maintain 11000 - you are supposed to be at eleven. We immediately climbed to 11000. (The visibility was good and as far as I know there was no traffic conflict). I told him I thought we were cleared to 6000 ft. He said he cleared us to maintain 11000 to the laned intersection and then to descent to 6000. He further stated that I read it back to him that way. Background: We were almost an hour late out of SHV due to a mechanical. At the time of the descent clearance I was conferring with the flight attendant on close passenger connections at DFW. (I was operating the radio. The F-O was flying the aircraft, there was no S-O). There was several items in the descent clearance - descent altitude, altimeter setting, and o.k. to disregard the speed restrictions and probably a couple of other things. If the controller did clear us as he stated, then I believe the situation occurred for three reasons. 1. I misunderstood the clearance or it did not register in my mind (the F O missed it also.) 2. Distractions in the cockpit by the flight attendant (not her fault). 3. The common practice of giving rapidly read descent clearances with several items in it.

The pilot heard the clearance, read it back (exactly as given), but wrongly interpreted the information. Where human beings operate at near maximum capacity, selective loss - undesired reduction of message complexity is apt to be involved [Ref. 5: pp. 336]. Information received during transmissions such

as this are handled by one's short term memory. Short term memory is a place where exact wording is stored for brief period of time, but there is a limitation to the amount of information it can handle [Ref. 6: pp. 135]. In the case stated above, the pilot was receiving a multiple input while trying to answer an attendant's inquisition. The added stress from being an hour behind schedule even further complicated the matter by occupying a portion of attention. The pilot's ability to deal with these series of events, without an error, is clearly exemplified.

2. Case Study 4887

Another incident involving distraction by a flight attendant occurred in Case Study 4887.

Narrative of Case Study 4887: Clearance was received by First Officer for flight to cross 15 DME W of FRR at or below 23000 ft. Flight attendant discussing cabin situation with Captain. Capt. believed 23000 restriction was for 10 DME and crossed 15 DME at little less than 24000 ft. At approx. 3500 FPM rate of descent previous cockpit coordination had been good and correct discipline maintained. For some unknown reason F/O failed to question or mention rate of descent necessary to cross correct DME point at altitude. Capt. believing crossing was 5 MI further east did not change descent rate as previously planned to cross the 10 DME fix at CR below 23000 ft.

The pilot's attention was removed from his duties in the cockpit causing a missed clearance. The missed clearance was further emphasized by the first officer not questioning the rate of descent. In many of these cases there are multiple reasons for the error - some overlapping, others enhancing the state of confusion. This action/interaction will be discussed more in depth in a subsequent section.

3. Case Study 4194

In Case Study 4194 it appears that the Captain was so engrossed in take-off procedures that he improperly read the take-off clearance, fixing in his mind 16000 ft. instead of 14000 ft.

Narrative of Case Study 4194: As Captain I misinterpreted the assigned flight ALT. As being 16000 MSL wherein we were assigned 14000 MSL. First Officer had read back clearance correctly when received from CDC RDO. However, we both neglected to set altimeter reminder (non ACCRAL SYS) to 14000. The ALT reminder was set at 16000 (previous legs assigned ALT). When the ATC CLRCN was received on ground, the reminder was not reset to 14000, As Captain, I was busy starting engines and misread the CLRNC to read 16000 ft. MSL instead of 14000 MSL. On climb out thru 15400 LAX CTR asked us our indicated ALT, we replied passing thru 15400 for 16000. He then issued us 16000 as assigned ALT. It is normal procedure for our airplane to reset the ALT reminder to 0 ft. When either CLRD for APPCH, or cancelling IFR CLRNC. This obviously was not done, and was a factor in this incident.

When dealing in multiple input situations, one must guard against uncontrolled breakdowns in automatic attentional responses. As seen in the chapter involving prior inputs, there is a correlation to the resemblance of the two. In prior inputs, a tendency exists to revert to a more familiar action in a parallel situation. In a multiple input scenario, a tendency exists to delete a step in procedure or to jumble the information being received or improperly execute a needed action. The attentional attitude required to "start the engine" is more automatic in nature than his clearance reception. That is, one becomes accustomed to a certain methodical pattern in preflight testing and take-off procedures. Receiving one's clearance is, of course, a normal portion of that

schema; however, it does vary usually from flight to flight. It has not been fully incorporated into the memorized pattern and could be the step most easily disrupted. The continual monitoring which should be present over "semi-automatic" actions is usurped by the automaticity of pre-flight check lists and starting check lists. Planning and decision making are processes that operate in the formation of intentions which are routine [Ref. 7: pp. 197]. These are actions under deliberate conscious control. When contention scheduling is complete without this deliberate control, without the involvement of supervisory attentional mechanisms, the response is automatic. When there is a combination of the automatic and semi-automatic, there tends to be a natural drift toward the automatic which overrides the supervisory control and lends a natural environment for error in the semi-automatic region.

4. Case Study 4087

In Case Study 4087, trouble-shooting (application of planning and decision-making processes to actions already in progress) is exemplified during a multiple input crisis.

Narrative of Case Study 4087: At lift off on RWY 8R our forward entry door warning LGT came on. A decision was made to return and land. APC vectored us for a base to RWY 17L and CLRD us for a visual, to contact TWR on final during this short period time, about 4 mins. The check lists were run, LNDG gross WGT ok'ed and while I worked APPCH control the First Officer was advising the CO. and MNTNC of our action. Turning base the First Officer returned to APC and I switched to the P.A. to advised the passengers of the problem and our intentions. Turning finals there was a momentary distraction over bug speed, as called by First Officer and what was indicated on my airspeed indicator. This was resolved and the APPCH made to a landing without contacting DEN TWR.

I believe the AMT of communication involved in such a short time, the fact that at one point each of us worked APC CTL while the other was attending to other contacts (plus the distraction at the point a change to TWR would normally be made) led to this oversight on our part, probably from a subjective assumption the other had made the TWR contact. The situation probably would not have developed had one crew member stayed in contact with CTL during the whole APPCH and it of course brings up the need for constant vigilance against assumption.

After lift-off, the forward entry door warning light came on and a decision to land was made. The aircraft was vectored for a base to a runway, they were cleared for a visual, and were expected to contact tower on final. The check lists were hurriedly expedited - gross weight checked and while the pilot worked approach control, the First Officer was advising the company and maintenance of action taken. During the base leg turn of the landing procedure, the first officer returned to approach control while the pilot went on the Public Address System to advise the passengers of the problem and intentions. During the turning to finals, there was a momentary distraction over the speed required to maintain flight verified by the First Officer and displayed on the pilot's airspeed indicator. This was resolved and the approach was made to a landing without contacting the tower. The pilot believed that the amount of communication in such a short time plus the distraction at the time a normal tower contact would have been made (in addition to assumption that pilot and co-pilot believed each other had made the contact - which will be discussed later) created the scenario for error. During the methodical pattern of landing procedures, which includes the contacting

of tower, a situation arose which momentarily removed the attention away from normal landing sequences at the exact time tower contact would have been made. Once the disruption was handled, normal routine was established - minus tower contact. An unexpected event arose which required an immediate decision making process to override ongoing contention scheduling monitoring, and deleted a step in the landing routine. It is not in the bounds of the author to state whether or not that the pilot replaced one action taken for the other action deleted. There was also the pilot's admission that both he and the co-pilot may have each assumed the other had made tower contact.

5. Case Study 3318

In another case of similar error (Case Study 3318), tower contact was also not made.

Narrative of Case Study 3318: We were inbound to MEM from NO., on a downwind, west of the airport, 35L and right were active. Visibility was 6 to 7 in haze. We were cleared for the visual to 35L with an altitude restriction to maintain 3000 ft we maneuvered for the approach but couldn't get a lower because ACFT B was on approach for 35R at 2000 ft, and we didn't have visual contact with this ACFT. By the time we saw the other ACFT and could be cleared out of 3000, we were well above profile and behind on check list and crew duties. In the rush, approach control either didn't turn us over to tower or we failed to respond to his instruction. In any event the landing was made without a proper landing clearance. Separation between the two ACFT was positive at all times and was never compromised. The only problem was that the visual search for the other ACFT and the delay in descent created an unusually heavy workload on the crew.

The pilot of that flight blamed an unusually heavy workload because of other traffic and improperly given vectors. Tower

contact was not made, but in this instance, no distraction occurred which caused the deletion as in Case Study 4087.

Even with the differences established in each case study in this section, there remains an element of duplicity. These errors occurred during some stage of a relatively fixed format of action, when input was arriving from several sources simultaneously. The format was a well learned behavior, of an automatic or at least semi-automatic nature. In three cases a disruption occurred which interrupted the ongoing contention scheduling and eventually, if not directly then indirectly, lead to an error.

C. PSYCHOLOGICAL REFRACTORY PHASE

In a communication system involving human units, errors can occur. The input (reception, message, data) and output (decision, action, transmission) do not always equal in content and meaning. A machine receives a signal and transmits the exact signal. In the area of human communicating, there are very few occurrences of reception and transmission without a certain amount of mental translation. Only rarely is input and output performed simultaneously. There have been studies performed which prove that the longer the delay between the two, or the more ambiguous the stimuli, the greater effect this has on the resulting transmission [Ref. 8: pp. 341]. The term used for this segmenting of input and output is "psychological refractory phase". It is during this phase that human beings implement various techniques

which: anticipate, rationalize, fill gaps, and create intelligent communication from distorted, imperfect input. During this data reception and transmission, it is possible to lose the initial meaning of the message completely. Transmission can also typically contain reconstruction and self editing for production of a smoother, more symmetrical copy. Human transmitters anticipate, suppressing remembered detail in order to format the data to conform to a desired action. A bias toward the transmitter's attitudes exists, as well as deviations from the original input, which reconstruct the output to become more pleasing to the recipient of the transmission. This can be especially applicable to situations where the recipient has important power over the transmitter, i.e. pilot over subordinate crew member.

1. Case Study 0138

Case Study 0138 yields an excellent example of human communications error due to anticipator monitoring.

Narrative of Case Study 0138: ACFT A was cautioned for jet blast from the departing ACFT B on RWY 19 and advised at pilot's discretion to taxi into position and hold. The Captain of ACFT A was working the radios and I, the co-pilot was at the controls. The Captain acknowledged the above clearance, I misinterpreted the clearance and was assured in my mind we were cleared for take-off, I taxied the airplane slowly onto the RWY to avoid the jet blast from the departing ACFT B, as I gave the aircraft takeoff power I heard the Captain say "cleared to go". After becoming airborne I held best-angle-of-climb to avoid the wake turbulence from the departing ACFT B. I put the gear in the up position, at that time I heard the tower issue us traffic on 29. The next thing I saw was an ACFT B pass slightly behind and below us as we crossed the 19/29 intersection. Then the tower came back and apologized for clearing us to take-off, we continued the flight as planned. Later I found out that

the Captain asked me "if we were cleared to go", I only heard him say "clear to go". If I had any doubts they were abolished by that statement. I don't know why I misunderstood the clearance, I haven't heard the tapes yet. I believe something in the clearance indicated to me we were cleared to take-off.

The aircraft was cautioned about the jetblast from another departing aircraft and advised, at the pilot's discretion, to taxi into position and hold. The pilot was working the radio. The co-pilot was at the controls. The Captain acknowledged the above clearances. The co-pilot "assured in his mind" that they were cleared to go, misinterpreted the clearance. The co-pilot taxied the plane slowly onto the runway to avoid the jet blast from the departing plane. As he gave the plane take-off power, he heard the Captain say "cleared to go" (when in actuality the Captain had just inquired from the tower, "Are we cleared to go"). The co-pilot stated later that he could not understand why he had misinterpreted or misunderstood the clearance.

It is easy to understand why the co-pilot misunderstood the clearance. He mentally translated the input to placate his anticipation. Campbell states in systematic error:

"Studies in perception and learning clearly indicate the loss of input elements in a complex and haphazard fashion, if not strictly random. But the operator does not produce an output of this type from meaningful or familiar material. Instead, through an anticipator monitoring of his own intended output, he makes an active effort to produce a coherent output by suppressing remembered detail that does not now seem to fit and by confabulating detail where gaps are conspicuous." [Ref. 9: pp. 342].

2. Case Study 2137

Another incident involving anticipatory monitoring occurred in Case Study 2137.

Narrative of Case Study 2137: After landing on 2MR which is one of the south runways, I taxied north toward the terminal building, which is north of Runway 26. The normal route was not used, due to about 1500 ft. of Runway 33 being closed. (Runway 33 is the normal taxi route) I mention that this information was not given to me by ground control or NTAMS or ATIS. This did not contribute directly to the incident, but indirectly. On arrival on Taxiway C, paralleling Runway 33 and holding short of Runway 26. I was Number 3 to cross Runway 26. However, there was another airline ACFT B outbound on Taxiway C on the north side of 26 which helped to create the problem. After sitting for a couple of minutes, ground control cleared ACFT B across Runway 26, but used the wrong trip number twice and also the pilot missed one transmission. By the time this was straightened out, it was too late for anyone to cross, due to departures off 26. After a couple more minutes, this trip was cleared across and I was Number 2 to cross. There had been several transmissions during this time that were broken or garbled and the outbound traffic was getting impatient about how they were going to get by the inbound traffic. After more waiting, there was a break in departures and they cleared two or three more trips across Runway 26 which I thought I was one. The First Officer tried to confirm this, but got no reply from Ground Control, which I took as another indication that we were already cleared. After crossing the runway and being almost to the gate, ground control asked if 660 was across the runway and the F/O replied, we were. Ground Control comments was good luck. I feel the cause of this incident (which happens very frequently here in Atlanta) is the fact that under normal conditions at busy times of the day, Ground Control frequencies are overloaded and jammed and handling more traffic than one man on one frequency can control and when taxi routes are closed it compounds the problem.

The aircraft had landed and due to the normal runway being closed, another was used. The pilot was vectored to a taxiway and instructed to hold before crossing another runway (a sort of intersection it seems with heavy traffic). A couple of

minutes elapsed. Control gave permission for another aircraft to cross this intersection, mixing up trip numbers twice, so in the confusion it was too long for anyone to cross. Several more minutes passed, outbound traffic was getting impatient. The pilot of the aircraft in question was getting impatient and there had been several garbled transmission. There was a break in departures and control cleared two or three more aircraft to cross the runway. The pilot understood he was one. His First Officer tried to confirm this, but received no reply from ground control. He took the silence as another indication he was cleared to go.

It is not stated what was in the transmission which caused the pilot to think he was cleared with the other aircraft to cross the intersection. General inclinations are that he created the clearance from the transmission to conform to his desired action. His impatience gave way to his anticipatory monitoring and he heard what he wished to hear.

3. Case Study 5680

Another aspect of error through misinterpretation is depicted in Case Study 5680.

Narrative of Case Study 5680: When the original clearance was received RWY 5 was in use. The clearance was a TULANCLINGO DEPT. (Via ME to TCG). Upon departing terminal the active runway was changed to RWY 23. After take-off on RWY 23R, departure control's clearance was to proceed to MW then turn right to heading 340 Deg. The co-pilot was flying the aircraft and apparently missed the clearance from departure control and started a left turn as per the TCG departure. Language problem contributed to the misunderstanding of the clearance, in the left turn I said to the co-pilot, "We were suppose to turn to the right", and he assured me the

correct turn was to the left. As we were in the left turn, departure control came on and advised us that we were cleared for a right turn. I explained that we had misunderstood the clearance and that we were proceeding to ME for ATCG departure. Departure control then cleared us to ME and a change of frequency, and at that time nothing more was said of the incident. In retrospect, better cockpit discipline would have prevented this incident.

In this flight, the First Officer was at the controls and apparently missed the revised clearance to turn right after take-off to a heading of 340 deg. He was following the original clearance, which instructed the aircraft to turn left. As the co-pilot was executing the left turn, the pilot informed him that they were supposed to turn right. The co-pilot - assured of his actions - insisted that a left turn was correct. During the turn, departure control came on and advised them that they were cleared for a right turn.

An analysis of this case done by NASA intimates that both pilot and co-pilot did not register the clearance. This is believable, otherwise why would the pilot let his First Officer talk him out of what he believed he heard. There has been considerable interest in the relative advantage of the first portion over the latter [Ref. 10: pp. 343]. In this case it seems the co-pilot retained the initial clearance and completely dismissed the later clearance when given. It is possible that he did not copy the second clearance due to high cockpit noise, inattention, or heavy workload. It could also be a factor of thinking left turn (as previously given) when actually hearing right turn. The co-pilot must have

been extremely sure he was correct to override the pilot's objection. Normally, an inferior will yield, not only to his superior's authority, but also to the experience that authority represents. Whatever the true cause, one should not rule out the possibility that the co-pilot anticipated what he would hear and confabulated the phrase to sublimate the anticipation.

4. Case Study 5699

This tendency toward making output like expected input, rather than different from expected input happens frequently [Ref. 11: pp. 349]. An excellent example of this is demonstrated in Case 5699.

Narrative of Case Study 5699: ATC told us to expect 250KT. and 10000 ft. restriction at saddle intersection, but didn't give us a clearance to descend. I repeat the clearance to the controller and asked the co-pilot who was flying if he understood, he said yes. ATC kept us 33000 ft longer than normal and did not tell us they had traffic at 31000 ft. We were well past normal descent point and I turned to get something out of my flight bag. While I was looking for the object the co-pilot started a descent without my knowledge. The altitude alerter went off and the co-pilot reset it to 10000 ft. I did not hear the alerter go off. ATC asked if we were descending, I looked at the altitude and we were at 31700 ft. I immediately told the co-pilot to climb and told ATC that we had left our altitude by mistake. He (ATC) then cleared us to 10000 and said we had traffic at 31000. The co-pilot had about 4 months as co-pilot. I think he became nervous that he was so high and turned the expected clearance in his mind to an actual clearance.

The Air Traffic Controller gave the flight an expected 250 KT at 10000 ft with a restriction at a certain intersection, but did not give them a descent clearance. The pilot repeated the clearance to the Controller and asked the co-pilot, who

was flying the aircraft, if he had copied it. The co-pilot replied in the affirmative. Air Traffic Control kept them at 33000 ft longer than normal and did not inform the flight of traffic at 31000 ft. They were well past the normal descent point, when the pilot turned to recover something from his flight bag. As the pilot was thusly occupied, the co-pilot began to descent without the pilot's knowledge. The altitude alerter sounded and was reset to 10000 by the co-pilot. Air Traffic Control asked if the aircraft was descending. The pilot checked the altimeter, acknowledged affirmative, that they had left their altitude by mistake. The pilot stated in the narrative that the co-pilot only had about four months in the cockpit. He also stated that he felt the co-pilot had become nervous that he was so high "turned the expected clearance in his mind to an actual clearance". Studies by Wyatt and Campbell (1950) indicated a stronger bias toward interviewer's expectations than interviewer's opinions in polling situations (which is intense). These expectations or "anticipations" are certainly exemplified in the cases presented in this segment.

5. Case Study 5740

In Case Study 5470, the co-pilot completely ignored the clearance because he did not understand it.

Narrative of Case Study 5740: Our aircraft arrived in OMA, I went into the operations office to check WX, and use the restroom. On returning to the aircraft I asked the F.O. if we had an ATC clearance. He replied that we did and I asked him what it was. He said cleared as filed maintain 5000 expect 11000 10 min. After departure

Our flight plans are all center stored and I asked him are we filed, to verify the routing I had on my center stored flight plan and his, as filed, was the same as MY as filed, namely V159 STJ direct MIC. The departure went normally and we were handed off to center (Minneapolis) As I flew the ACFT on the previous routing to 11000 and we crossed OMA VOR and proceeded on course V159. Approx. 25 NM S.E. of OMA VOC as we were being handed off to Kansas City center Minneapolis asked are you flying the Omaha 1 arrival. I answered that we weren't that it was my understanding we were cleared V159. He said that we weren't but we could work it out with Kansas City. Hand off was detected and Kansas City turned us to 165DEG. And vectored us the approach gate at Kansas City. I again asked the F/O for the clearance that he copied and he said that it was his mistake that he did not know what Omaha 1 arrival meant and that he checked my approach plates and his and neither of us had a Omaha SID. by that name so he ignored it but read the clearance back, Kansas City as filed maintain 5000, expect 11000 10 min. after departure. And that Omaha clearance delivery accepted the read back and that he did not think to ask me about Omaha One arrival when I returned to the aircraft. I felt like I had been sold down the river by an otherwise very trustworthy, competent F/O. Clearly, he made a serious mistake as I suppose I did in not checking the clearance with clearance delivery. To do so however would surely leave your F.O. with the feeling that, this guy doesn't trust me, which is now the case. But on the other hand trust, coordination are definitely necessary for a safe operation. While cross check is a healthy, worthwhile cockpit activity, it becomes counter productive when one crew member feels he is getting a check ride from the other crew member. For this reason, I probably won't question the next clearance I get from this or any other F.O., but I'll be uneasy. The nagging fear that he may have miscopied or misunderstood will be in the back of my mind. Many of our days require 14 hrs in the cockpit. The physiological needs of crew members necessitate that all are not going to be present in the cockpit at all times.

This tendency, of course presents a more conscious effort to override the received input, and indicates the bias toward personal attitudinal display.

6. Case Study 3077

Human units engaged in communication can receive data and during the transitory process segmenting input and output, interpolate what they consider to be a more logical method of implementation. In Case 3077, this occurred as a flight was being vectored for an approach.

Narrative of Case Study 3077: While being vectored for an approach and landing on RWY 22R approach, the following took place. Approach control when queried as to other traffic stated that we were his only IFR traffic but numerous others were arriving from other sectors and that he was working on a slot for us. The potential problem arose as the controller turned and descended us from a close high right downwind leg (040 DEG. HDG.) to a 080 DEG. heading, while calling out the position of the traffic we were to follow on final. The Captain mistook the heading to be 180 DEG. as this was a logical heading to intercept final as the downwind as somewhat tight to the runway. I acknowledged the 080 DEG heading and look out the window for the 1:00 o'clock traffic at 3 miles. The only traffic I saw appeared a 2:00 to 2:30 and looked to be 5 or 6 miles. I asked the controller if this was our traffic and he replied with "What's your heading" I looked back into the cockpit to discover we were turning thru 170 DEG. I told the controller we were 170 DEG correcting back to the assigned. At this point the Captain and I saw our traffic at 11:00 o'clock 2 1/2 to 3 miles. The controller said the heading should be easterly. I then acknowledged the traffic and we were then cleared for a visual approach. We made a left turn and one S turn to position ourselves behind the traffic and proceeded without further confusion to the airport and landed. The conditions here in marginal VFR weather could be a setup for a near miss or mid-air. Fortunately, we were in clear air. Pilots and controllers anticipating visual approaches to expedite arrivals, save fuel and in general ease the burdens of day to day air operations situations. Hopefully this contribution can be of assistance in developing procedures and techniques for smoother and safer transitions.

Approach control, when queried as to other traffic, stated that they were his only traffic but numerous other aircraft were arriving from other sectors and that he was working on

a slot for them. The potential problem arose as the controller turned and descended them from a close high right downwind leg (040 degree heading) to an 080 degree heading while calling out the traffic they were to follow on final approach. The Captain mistook the heading to be 180 degrees, as this was a logical heading to intercept final approach since the downwind was rather tight for the runway. The co-pilot acknowledged the 080 heading and began to search for traffic, only to discover it was in the wrong place. When the co-pilot asked control if that was the traffic, control replied, "What is your heading?" The co-pilot checked the cockpit and found that they were on a 170 visavis 080 degree heading and informed the pilot. After vectoring to the proper heading, they were cleared for a visual and proceeded to land. The co-pilot stated that pilots and controllers who are anticipating visual approaches might (in order to expedite arrivals, save fuel, and in general ease the burdens of day to day air operations) enter into this type of potentially hazardous situation. The pilot, in this case, used his own judgment for confabulating the given heading to read what he thought as a more logical heading.

D. INFERENCE SHORTCOMING

There are twenty-two case studies represented in this thesis. Nine of these case studies provide examples of error by assumption. Webster defines assumption as, "... the act of taking for granted, or supposing; a supposition." In

their book Human Inference: Strategies and shortcomings of social judgment, Richard Nisbett and Less Ross thoroughly examine error by human inference (assumption) [Ref. 12 pp. 7]. It portrays people as intuitive scientists who are gifted and generally successful, but whose attempts to understand, predict and control events in the social sphere are seriously compromised by specific inferential shortcomings [Ref. 13: pp. 3]. It is this tendency to predict and control events merely on intuitive cognition that pertains to the case studies in question. The same tools the intuitive scientist uses which cause success, also lead to error. These tools are labeled by Nisbett and Ross as "knowledge structures" and "judgmental heuristics".

Knowledge structures include events or data which exist in the human memory. These knowledge structures label and categorize objects and events quickly. They also define a set of expectations about objects and events and suggest appropriate responses to them. Judgmental heuristics are divided into two subcategories: representativeness heuristics and availability heuristics. Representativeness heuristics allows the individual to reduce many inferential tasks to what are essentially simple similarity judgements. An object or event is assigned to one conceptual category rather than to another according to the extent to which its principle features represent one category more than another. The availability heuristic is implemented when judging frequency

and statistical probability and is fallible because more factors are involved than just these two.

An application of this data to the cockpit environment is easy to portray. The crew is taught procedures through repetition of action and an application of one's experiences. In fact, a "seasoned" pilot is highly regarded. He/she has succeeded in making many decisions, judgments, and actions in a fashion which displays knowledge and intuitiveness. As stated before, the very elements leading to success can also lead to error. The line of demarcation dividing the two is faint but existing. There are those areas which lie beyond the realm of inferential deductions - assumption. Pure fact and data are needed. This is one area in which machines excel - machines do not assume. Human units use previous knowledge and experience to reduce the complex tasks of assessing probability and predicting values to simpler judgmental operations. In general, these mental actions are useful, but they can lead to severe and systematic errors [Ref. 14: pp. 326]. Pilots should guard against using knowledge structure and judgmental heuristics in lieu of precise data.

1. Case Study 2536

An example of implementation of knowledge structures is presented in Case Study 2536.

Narrative of Case Study 2536: The Captain was flying, myself co-pilot copies change of clearance from J79.1LM ARL to direct HAW ARZ after copying clearance I looked at the Captain and though he indicated he got the new clearance as he changed the VOR FREQ from 1LM to HAW. But due to the high noise level in the cockpit he did

not hear all of the clearance. After HAW he kept what appeared to me to be a wind correction, unknown to me he was proceeding to LLM. Just about LLM the center questioned our route of flight, then immediately changed our clearance back to LLM-ARL. No evasive action required.

The co-pilot thought the pilot understood the clearance, but due to high noise level in the cockpit, the pilot did not hear all the clearance. The pilot "gave an indication" that he had received the clearance. More than likely, the co-pilot drew upon past experience with this pilot and read body language to be reception of clearance. (Body language being nodding of head, movement of hand, or facial gestures which might indicate an affirmative reply.) The analysis of this incident states the danger involved. "An assumption on the co-pilot's part that could have led to serious consequences had other traffic been involved. An example of what can result when all clearances are not verified by all crew members." The co-pilot should have received verbal acknowledgment of the clearance instead of relying on inference.

2. Case Study 2933

In Case Study 2933, an example of availability heuristics is portrayed.

Narrative of Case Study 2933: On the ground at PAX the F.O. called for ATC clearance SEA. Clearance was as filed - maintain 9000 - expect FLT level 200 3 min. after departure. Departure FREQ. and transponder code was also given. I missed the first portion of the clearance and picked it up at F.L. 200 (the center stored ALT.) and got the FREQ. and transponder code. I set 20000 in the ALT. Alert unit and set in the transponder code as the F.O. read back the clearance, again I did not hear the 9000 restriction and asked if we were cleared as filed - the F.O. answered yes. I thought I understood the entire clearance. The F.O.

made the takeoff and I changed to DEPT. control and reported leaving 1000 FT and climbing to F.L. 200 - the controller said ROGER and gave us additional climb instructions which included a heading change at 2500 FT at about 800 FT the F.O. asked if we had been cleared to 20000 and I replied, Yes - at 10000 FT the controller asked what ALT. We had been to and again I replied 20000. He said we should have been stopped at 9000 then cleared to F.L. 200 and asked us to expedite thru 11000 which we did. The F.O. later said we had been cleared to 9000 originally, but thought we had been recleared to F.L. 200 and he had missed the reclearance. The crew composition helped create this situation as the F/O regularly flew this trip, the Capt. was a management pilot who hadn't flown the route recently and the S/O was a reserve who was totally unfamiliar with the route. The F/O on taxi-in at PDX, unknown to the Capt. had set 9000 FT in ALT. ALERT SYS. in anticipation of what he knew was a normally ALT. restriction for departure, when the Capt. thought the was given F.L. 200 with the clearance he set in that altitude replacing the 9000 FT - this was missed also by the F.O. and he read back the clearance and was not rechecked for a proper setting prior to takeoff. The Capt. checked in with departure control after takeoff and stated he was climbing to F.L. 200 and received no correction. When the F.O. asked if we had been cleared to 2000 FT and got a positive answer he assumed he had missed something and continued to climb thru 9000 FT.

While awaiting departure the First Officer checked with the Air Traffic Controller to see if the clearance was as filed. Air Traffic Control replied maintain 9000 FT and expect flight level 20000 FT three minutes after departure. The departure frequency and transponder code was also given at this time. The pilot missed the first portion of this clearance, hearing only 20000 FT. He picked up the departure frequency and the transponder code as the First Officer read back the clearance, still missing the 9000 FT restriction. He asked the First Officer if they were cleared as filed and the First Officer replied in as affirmative. The pilot believed he had understood the entire clearance. He inferred, filled gaps,

thinking what he understood was correct. (Had the co-pilot read back the entire clearance at this point all misunderstanding would have been alleviated.) The First Officer made the take-off and the pilot changed to departure control and reported leaving 10000 FT and climbing to 20000. The Controller said, "Roger", and gave them additional climbing instructions which include a heading change. At 8000 FT the First Officer asked if they had been cleared for 2000 FT and the pilot replied, "Yes." At 10000 FT the Controller wanted to know what altitude they had been cleared to and the pilot stated 20000 FT. The Controller told them they should have leveled off at 9000 FT. The First Officer later stated to the pilot that they had originally been cleared to 9000 FT. The co-pilot was used to flying this route and had preset the altimeter alarm at 9000 FT. The pilot, not knowing this, had reset it to 20000 FT. The co-pilot assumed he had missed the reclearance when he asked the pilot if they were cleared to 20000 and received a positive reply. The co-pilot had concluded a set of expectations from affirmative inference he had received from the pilot and the fact that the altitude alarm had been changed. He "deduced" that the pilot had received another clearance with the additional climbing instruction. Nesbitt & Ross state:

"The availability heuristic is used to judge the frequency and likelihood of events and event-relations. Since the availability of remember events is sometimes biased at the stage of sampling, sometimes at the stage of encoding, and sometimes at the stage of retrieval, frequency and likelihood estimates often will be biased correspondingly." [Ref. 15: pp. 42]

3. Case Study 5381

In Case 5381, judgmental inference using representativeness heuristics is depicted.

Narrative of Case Study 5381: Myself and the rest of crew dead headed from HIS to PIT on Flight 204 and proceeded to Gate 16 where outbound equipment for Flight 231 was scheduled for departure at approximately 1340E. We found Flight 287 still on gate. Maintenance informed us our aircraft was still at the hanger and would be parked on Gate 16. We left our bags and proceeded to operations. In operations we checked T.V. monitor which indicated Gate 16 aircraft still at hanger. I proceeded in completing of flight plan which indicated PIT to SDF fuel load 22000 lbs. Captain Whelchel and myself discussed enroute weather of thunderstorm lines etc. Periodically checking TV monitor. At approximately 1355E (1755Z) the TV monitor still indicated aircraft at hanger but decided to proceed gate anyway. Captain and myself arrived at Gate 16 at approximately 1400E (1P00Z) and found aircraft at the gate. I performed walk around inspection while Captain boarded the aircraft. When I boarded the aircraft I found fuel slip for 24600 lbs in area of radar scope and placed it on my side assuming that extra fuel was added because of weather enroute. I proceeded to read check list to Captain and at fuel, oil, hydraulic quantities checked fuel slip and informed Capt. I had fuel slip and completed check list. We were ready for push back at 1410E (1810Z) on schedule and contacted ground control, also during, push back I was receiving ATC clearance. After completing after start check list proceeded to Runway 28R, completing before take off check list. At this time I added an additional 2600 lbs of fuel to take off weight and gave corrected take off weight. Since it was my leg to fly, I performed normal take-off at 1416E (1816Z) and climb out. At approximately 15000 FT. I changed to center tank and noticed no fuel in center. I immediately looked and informed Captain that no fuel was in center tank, who by this time was looking at fuel quantities also. Captain said "something crazy here". We leveled off at approximately FL210 and I pulled power back while we were determining the problem. After discussing the matter, we decided we had to go with the present place for landing to have checked. We contacted systems control and received amended release to CMH at 1427E (1827Z) 11 minutes after take off. At this time, during descent into CMH we informed flight attendants of the problem and that we were landing at CMH, also informed normal landing at 1447E (1847Z) and taxied to gate. At the gate, we had dip sticks and all gauges checked and

found fuel to agree with indications. We had aircraft fueled and informed passengers that the problem had been corrected and we were taking on additional fuel as a precaution and for weather. We then proceeded to SDF with everything normal.

During a pre-flight inspection, the co-pilot discovered a smudged fuel slip in the cockpit. The fuel slip was for more fuel than needed on this particular flight, but the co-pilot "assumed" the extra fuel was to compensate for bad weather they would encounter enroute. The co-pilot proceeded to read the checklist to the Captain and at fuel, oil, hydraulic levels checked the fuel slip and informed the Captain that he had the fuel slip. It was not until take-off, during a routine check of fuel tank gauges, that the pilot and co-pilot simultaneously noted that there was a low reading on the amount of fuel on board.

The co-pilot made his judgment based on the perceived similarity of the known "like characteristics" of the event to the presumed essential characteristics of the category [Ref. 16: pp. 42]. He knew that extra fuel would be needed in rough weather, he found the fuel slip on the aircraft in the radar area (not an unusual place for a fuel slip to be left). Therefore, he decided that this fuel slip was for his flight. Nesbitt and Ross state:

"The representativeness heuristics of a given structure, including the similarity of quite superficial and incidental features of the stimulus to features of the stimulus to features of the structure, may be the chief determinant of the arousal and application of a given structure." [Ref. 17: pp. 42]

The co-pilot made his assumption based on events of similar structure. The factors he had used in weighing his decision were great enough to remove any doubts that the fuel slip was not for the aircraft in which it was found.

The application of knowledge structures, availability heuristics and representativeness heuristics to the case studies presented, indicates how the human unit might apply them to a cockpit environment. As stated in the beginning of this section, their use in everyday matters for judgmental actions can lead to kudos as well as errors. It is not the existence of heuristics and knowledge structures that is being criticized, but their overuse, misuse, and use in preference to more appropriate strategies [Ref. 18: pp. 42].

E. LEADERSHIP AND CREW COORDINATION

The cockpit environment supports a mini-organization. Within this organization exists a social hierarchy. The leader of this hierarchy is the captain. He is the one person held responsible for his group's goal directed behavior. An individual established in such an authoritarian position is expected to plan, coordinate, direct, and control the task-relevant activities of those individuals for whom he has responsibility [Ref. 19: pp. 318]. By being captain and enforcing the authority needed to achieve the directed goals, this person of responsibility is demonstrating "leadership". While in this position of responsibility the captain of the aircraft may be expected to direct the behavior of others,

and reward or reprimand according to performance of duties assigned or established. The leadership a captain displays while in command of a commercial aircraft is essential to the lives of the passengers and crew aboard as well as the safety of the ground crew personnel. The captain has not attained his position simply on the ability to influence his subordinates, or the skill with which he can fly the aircraft, or by the instinct, common sense, and intelligence that might enable him to make command decisions. It is a combination of these three traits that are required, plus an innate sense to recognize situational and individual factors, which comprise the leadership capabilities of a captain.

As stated in the previous paragraph, the captain is the leader of the social hierarchy, or group, in the cockpit. The captain, crew and passengers all are members of this group. It is particularly cohesive society with its own code of behavior. The passengers onboard strongly need to believe in the crew. The crew wishes to fulfill their obligations in a way which pleases the passengers. This is further emphasized by the owner of the airline to which the crew belongs. Therefore, within the aircraft there exists a high degree of group conformity, and a strong reciprocal and interacting desire to please [Ref. 20: pp. 138]. Precise crew coordination and an effective leadership are traits essential to the sublimation of this group goal. There are times when a need to conform or to please prohibits achievement of the group goal.

In previous sections, different aspects have been discussed which have led to errors in the cockpit environment. Leadership and crew coordination, when properly implemented, could alleviate the error in many instances. On the other hand, lack of these two traits could further enhance an already bad situation. Proper interaction between pilot and co-pilot is needed at all times. The desire to please, however, can stand in the way and attainment of an error-free flight placed in jeopardy. Unless the co-pilot is given some take-offs and landings, and opportunities to make his own judgmental decisions, he begins to have a low opinion of himself as simply a flap-raiser and general dogsbody. His opinion of his captain is formed largely from how much independence he is allowed. In order to maintain good cockpit relations, there is pressure on the captain to allow his first officer these opportunities.

1. Case Study 5680

In Case Study 5680 (discussed previously in the section dealing with the psychological refractory phase) the first officer insisted his turn to the left was the correct maneuver. The captain, who had heard the clearance correctly, informed the first officer of the error. However, the first officer overrode the arguments of the pilot and proceeded with an incorrect turn. The intertwining of the two elements (lack of leadership and the psychological refractory phase) emphasizes that several factors can contribute to or enhance

the error that occurs. In this case, had the captain been more aggressive in asserting his leadership the error could have been halted before departure control discovered it.

2. Case Study 5740

Another incident exhibiting a captain's submission to a co-pilot is depicted in Case Study 5740 (see section on inferential shortcomings for narrative). The captain had departed the cockpit to use the restroom and left the co-pilot in full command. While the captain was gone the co-pilot received a clearance he did not fully understand. Rather than seem a fool, for not understanding, he ignored that part he did not understand. When the captain returned the co-pilot did not ask him for an explanation. Eventually, the error caused by the co-pilot's stupidity was discovered by Air Traffic Control. The pilot very explicitly stated in the narrative how he felt about the entire sequence:

"I asked the First Officer for the clearance he had copied. He said that it was a mistake. That he did not know what Omaha One arrival meant by that name so he ignored it but had read the clearance back as given and that Omaha clearance accepted the readback. He did not think to ask me about Omaha One arrival when I returned to the cockpit. I felt like I had been sold down the river by an otherwise very trustworthy, competent First Officer. Clearly, he made a serious mistake as I suppose I did in not checking the clearance with clearance delivery. To do so, however, would surely leave your First Officer with the feeling that this guy doesn't trust me, which is now the case. But on the other hand, trust and coordination are definitely necessary for a safe operation. While cross-checking is a healthy and worthwhile cockpit activity, it becomes counter productive when one crew member feels he is getting a checkride from the other crew members. For this reason, I probably won't question the next clearance I get from this or any other First Officer, but I'll be

uneasy. The nagging fear that he may have miscopied or misunderstood the clearance will be in the back of my mind. Many of our days require 14 hours in the cockpit and the physiological needs of crew members necessitate that all are not going to be present in the cockpit at all times."

This case study is also an example of the First Officer trying to please the captain. In 1960, the psychologist Harvey found that the second highest member of a group was the most conforming [Ref. 21: pp. 149].

The status of the captain in the small group community of the cockpit may exert pressure on the rest of the crew members to conform to his way of thinking or completing a given task. It may hinder intelligent interaction and adequate monitoring. Norms have defined the respective roles on the flight deck, and regulated the overall hierarchy of behavior within the group. One of the more deadly-forms of conformity is that it may inhibit action, making a person yield his right to express an opinion.

This is quite evident in Case 2933 (see the section on inferential shortcomings for this narrative). The First Officer had routinely flown this route, the captain was a management pilot. The pilot who had missed most of the clearance reset the altimeter which had been preset by the co-pilot prior to departure. The co-pilot knew what the clearance would be because CMS he flew this particular flight regularly. As they exceeded the proper clearance level, the co-pilot did not question the pilot's actions. He more or less assumed the pilot knew what he was doing.

The First Officer provides the feedback for the captain. If he mirrors his agreement (or fails to voice his disagreement) over some faulty assessment of a flying situation or over some wrong flying technique, the captain will receive reinforcement for his error and the aircraft may be doomed [Ref. 22: pp. 149].

Crew coordination and leadership are two essential elements in a cockpit environment. They promote careful monitoring and quick action which are needed safeguards against errors. In addition, one of the biggest safety devices in an aircraft is individual judgment and nonconformity. The truthful support of another human being on the flight deck in regard to air safety cannot be exaggerated. As a leader, the captain should realize the value of the other crew member's judgment, even when it differs from his own. He should not, however, override his own experience and knowledge. The balance is delicate, with trust being an unstable equalizer.

III. THE ADVENT OF DSS TO THE COCKPIT ENVIRONMENT

There has been much emphasis placed on the fallability of the human unit in previous sections of this thesis. This is, after all, a study of documented errors in human communication, whether it was a breakdown of communication between two human units or the incorrect reception or interpretation of data from a single unit. In remembrance to an often quoted passage ... "To err is human," ... One must take into account the fact that these errors studied could have led to fatal consequences. There has been an abundance of bruhaha over the fact that statistically one is far safer in commercial aircraft than on the streets and highways of the world. Statisticians weigh bulk numbers, calculating percentages of possible death in various environmental situations. And in looking at these vast numerical chartized accounts of human mortality, one discovers himself to be in greater safety in a large jumbo jet than anywhere in a four block radius of one's home. Then why the intense interest in our busy skyways? Perhaps it is because the value of one life, no matter where it is accidentally terminated, cannot be calculated. There are studies in all fields, all endeavors, to determine safer ways, methods and ideas which might maximize the number of injury/death related circumstances. The cockpit of commercial aircraft is no different, it does not escape the

scrutiny which is constantly and increasingly being made possible by modern technology. The modern technology of today's cockpit environment is the application of a decision support system - computerized digital avionics.

What exactly is a Decision Support System (DSS)? What kind of system are being implemented in the present aircraft and how do they "support"? What does the future promise for the DSS in the cockpit environment. These questions are the basis for the final section.

A. DEFINITION OF A DECISION SUPPORT SYSTEM

The best definition of a DSS that this author has uncovered is in the introduction of Peter G. Keen & Michael Morton's book, Decision Support System: An Organizational Perspective. They state: ---

"Decision Support System (DSS) represent a point of view on the role of the computer in the management decisionmaking process. Decision support implies the use of computers to

1. Assist managers in their decision processes in semistructured task.
2. Support, rather than replace, managerial judgment.
3. Improve the effectiveness of decisionmaking rather than its efficiency [Ref. 23: pp. 1].

The key to a DSS is the human unit. It is the human unit that utilizes the DSS to arrive at decisions and process data. A decision algorithm, a decision rule, or a computer program assists by providing the basis for a decision. Gordon B. Davis states in his Structure of a

Management Information System,

"Software cannot make a choice since choice is a human activity. However, software can be used in ranking the alternatives and otherwise applying decision choice procedures to support the choice itself." [Ref. 24: pp. 334].

The manager (in this instance pilot or co-pilot) uses the DSS to implement arrival at a decision. It would also be used to selectively ask for information, provide graphical summaries or time-series analysis as well as arrival at simple computations, comparisons and projections. The system is like a sophisticated calculator, preprogrammed to include some of the manipulations the manager used by habit for such problems [Ref. 25: pp. 97]. With the DSS, facts or information are easily retrievable - making relevant information accessible almost immediately. These elements of the DSS, their attributes and applications provide the crew member with the ability to recognize or decide what constitutes the problem and help create alternatives in order that a decision may be reached.

With all the high technology within today's world, what prevents the computer from total usurpation of all decision-making? There are, indeed, areas that can be handled without the human unit. Programmed decisions is an area of total computer application. A programmed decision is one that is well-defined and is repeated often enough that decision rules or decision algorithms may be well defined [Ref. 26: pp. 321]. Nonprogrammed decisions are not repeated, or not

repeated frequently, or they are so different at each repetition that no general model can be developed as a basis for programming them. The heuristic approach of the human unit which has been proven to lead to serious difficulties in the section on inferential shortcomings enables this unit to arrive at conclusions by examining data for which no algorithm for processing exists.

Software support for generating solutions can also consist of a structured approach to the problem. In this way, the computer program leads the decision maker in a rational search strategy for solutions. These questions might be followed by a series of questions which help the decision maker to consider alternatives. The advantage of structured approaches is that they assist in systematically exploring the normal decision space. There is a disadvantage, however; a tendency to suppress search outside the normal decision space also exists [Ref. 27: pp. 355].

Application of the DSS in the cockpit environment will be discussed in the following section. It will be shown how both programmed and nonprogrammed DSS is being implemented.

B. COMPUTERIZED DIGITAL AVIONICS

Computers have emerged into the aviation field as key tools in every aspect of its industry - from design and development, to application in flight. Computers are now absolutely essential in every niche and cranny of the industry. Augmenting the use of computers across this broad

range of applications is computer graphics, the integration of computer hardware, software and display technologies that produces graphic output [Ref. 28: pp. 64].

One of the more recent advances of avionics technology, which is founded on powerful microprocessors, is providing pilots with graphic displays of the world beyond the confines of the cockpit. The computerized graphics "vision" for commercial aircraft includes weather radar, map navigation, landing systems, performance monitors for engines, controls, altitude and other onboard equipment. Electronic flight instrument systems (EFIS) are not only replacing electro-mechanical devices, but are providing flight crews with new data, such as moving map navigation. On the display screen important flight information, such as flight clearance is highlighted, by appearing brighter, color coded, and in front of data of lesser immediacy, i.e., weather radar. These systems will help eliminate many of the clearance errors, which were exemplified in the case studies. New digital flight management systems are maximizing efficiency by automatically flying an aircraft along an optimum flight path.

Color cockpit CRT displays are increasing the amount of information a pilot can absorb in a finite time frame. The new Boeing 767 has a prototype display of the electronic attitude director indicator (EADI). It portrays the sky as a traditional blue field and the aircraft by yellow/tan "wings" on either side of a small white square. The white

line separates the sky from the black earth emphasizes the artificial horizon. A roll scale of white radial lines appears at the top of the display, and there are white and blue horizontal lines for a pitch scale in the center. The green glide slope deviation scale and magenta pointer are displayed along the left side of the screen. The green speed deviation scale and magenta pointer are on the right. This display area is 4.7 in. wide by 4.2 in. high.

In some applications, as in the blue sky field on the EADI, color is used in the electronic instructions to retain the conventional appearance of an instrument. Its chief purpose, however, is to facilitate differentiation between diverse categories of information.

Color also is used to heighten contrasts in weather data, i.e., in a manner similar to that used in false-color processing of satellite imagery. A total of seven stable controllable colors are used in the flight instrument displays, but others could be added.

There are many avionic advances in use on the Boeing 757 and 767. These include:

- Programmable central digital warning and caution system
- CRT keyboard/display unit for the Sperry Flight Systems Flight Management System
- Digital auto-pilot and flight director system
- Thrust management system
- An electronic horizontal situation indicator (EHSI) that allows the pilot to page through displays to select a route for inserting into the flight management computer

Within the flight management system two kinds of data are stored:

1. Locations of Airports, VOR stations and other hard data. This information also is used to initialize the Boeing 767's inertial reference system.
2. Selected company routes and standard departure and arrival routes (SIDS and STARS) [Ref. 29: pp. 57].

The thrust management system is designed to eliminate essentially all throttle stagger and insure that an engine will provide take-off thrust (but no more) anytime the throttle is moved to the full forward position. By contrast, most engines in current aircraft exceed engine limits if a throttle is pushed to the physical stops. The thrust management system combines a primary digital electronic system with a backup conventional hydromechanical one. The aircraft can be flown with only the hydromechanical controls.

C. FUTURE OF DSS IN THE COCKPIT ENVIRONMENT

These systems onboard the new Boeing 757 & 767 are today's application of the computer into the cockpit environment. What wonders lie in store for the future? The May 11, 1981 issue of AWST brings forth the use of voice interactive avionics.

Using a verbec connected-speech, speaker-independent type of speech recognition equipment with a working vocabulary of approximately 70 words, the FAA has demonstrated that it is feasible for a pilot to file a flight plan

directly into a computer without human intervention. The FAA also plans to evaluate the use of voice recognition equipment as a means of directly "driving" the technical center's digital traffic control simulator.

Speech recognition systems currently are available from seven commercial suppliers, but they are designed for use under operating conditions that are far more benign than an aircraft cockpit.

Growing numbers of military and civil aircraft will be outfitted with "talking avionics" for a variety of functions. This is a result of rapid advances in microcircuits than can generate a natural-sounding voice coupled with low cost resulting from growing consumer market applications. The initial application of voice warnings on the USAF/General Dynamics B-58 Hustler proved too cumbersome, expensive and unreliable. Since that time, the cost of synthesized - voice microcircuits has dropped significantly, and the vocabulary versatility has increased.

The use of the highlighted CRT could be invaluable in minimizing many of the clearance problems encountered in the case studies. A "file drawer system", i.e., each step of the clearance is highlighted as execution of a previous step is completed would allow the flight crew to know exactly where they are at the present, clearance wise, at all times. This way he/she would be receiving the clearance not only verbally but visually as well. This system of counter-checking would

save time since the pilot or co-pilot would not have to physically write down the clearance.

It is easy to project that all the varieties of duties that computers are able to accomplish in today's space shuttle industry will soon be applicable to the commercial aircraft. The military now has drone plane and the Tomahawk Cruise Missiles - both pre-programmed or directed from ground control. Perhaps one day, the airlines of the future will not require a human unit, just hardware and software. to reach a destination.

IV. CONCLUSION

In looking over the 22 case studies presented by NASA, it is very simple to recognize areas where a DSS could be utilized. A DSS in the cockpit environment could become the third crew member, the one who would not anticipate or assume, who could not hold a rank prejudice, who would not be susceptible to the "human element". In fact it would be the crew member which would provide countermeasures to the human element.

Modern technology has not yet provided the aviation industry with a viable cost-efficient method of total elimination of the human unit from the cockpit of commercial aircraft. That reality is still in the land of tomorrow. What we do have (as related in the cockpit description of the Boeing 757 and 767) are decision support systems which can support.

The new digital flight instrument panels with computerized flight maintenance systems will greatly assist those areas specified as "psychological refractory phase" and "reductive coding". Perhaps the greatest area helped of the four discussed in this thesis, will be the one entitled "reductive coding". With more of the input data being programmed into the computer system of the aircraft, there will be less tendency toward error. The pilot will

have more time to make clear, concise decisions in attending to regular duties as well as emergency situations which might arise.

Retroactive Interference could be at least made less of a threat with the use of programmed flight plans (SIDS and STARS) and a wide variety of electronic alarms to indicate deviations from a scheduled maneuver. The DSS would not, however, prohibit initial input of incorrect data. The human element, in all its fallability, could easily continue creating errors. Perhaps the only true safeguard against lapsing into prior input errors is constant vigilance and awareness of the possibility that it was feasible. This is also the case for errors by "inferential shortcomings".

Human inference does not need to be eliminated. In fact, judgmental decisions based on inference are the factors that the human unit can contribute to the DSS. The errors related in the case studies presented on human inference could have been avoided had proper cockpit discipline been maintained. If procedures are completed in specified sequence, errors by assumption would be decreased.

Lack of leadership and poor crew coordination lie totally on the human side of the cockpit environment. The only way to erase errors due to these element would be elimination of the human unit entirely. Training in communication skills would do a great deal in bringing the problem into awareness of the flight crew, as would careful selection of those placed in command.

A DSS can provide a wide variety of levels of support. The DSS's in operation in today's airlines are able to enhance the pilot and co-pilot's ability to achieve all the goals needed for safe flight. In congruence with the support, careful attitude and attention to proper sequence and duty by the human units can make the flight not only safe, but also error-free.

APPENDIX A

INCIDENTS COMPILED BY NASA

ACCESSION NO.

0138 NARRATIVE

:ACFT.

A was cautioned for jet blast from the departing ACFT B on RWY 19 and advised at pilot's discretion to taxi into position and hold. The captain of ACFT A was working the radios and I, the co-pilot was at the controls. The captain acknowledged the above clearance, I misinterpreted the clearance and was assured in my mind we were cleared for take-off, I taxied the airplane slowly onto the RWY to avoid the jet blast from the departing ACFT B, as I gave the aircraft takeoff power I heard the captain say "cleared to go". After becoming airborne I held best-angle-of-climb to avoid the wake turbulence from the departing ACFT B. I put the gear in the up position, at that time I heard the tower issue us traffic on 29. The next thing I saw was an ACFT B pass slightly behind and below us as we crossed the 19/29 intersection. Then the tower came back and apologized for clearing us to take-off, we continued the flight as planned. Later I found out that the captain asked me "if we were cleared to go", I only heard him say "cleared to go". If I had any doubts they were abolished by that statement. I don't know why I misunderstood the clearance, I haven't heard the tapes yet. I believe something in the clearance indicated to me we were cleared to take-off.

Reporter's Recommendations: I wish the controller would have said, "taxi into position and hold". I took off because I thought the tower had cleared us to go, when the captain asked me, "if we were cleared to go". And I misunderstood the statement for "cleared to go", it confirmed my belief. I believe the incident would have been avoided if the tower had issued shorter clearance and a better cockpit procedures had been used.

ACCESSION NO.

1179

NARRATIVE

Shortly after passing MOD (Modesto), OAK ATC cleared us to cross CEDES at 11,000 and 250 KTS, the first officer was flying the airplane and he thought ATC wanted us to slow down at that time and then descend. I re-checked with ATC and they confirmed that they wanted us to cross CEDES at 11,000 at 250 KTS and we could slow down any time we wanted to. They also advised that if we would have any problem in making those restrictions they would waive them. I told them we could probably make it O.K. about 12-15 miles east of CEDES were given a clearance that was hard to read and about all we got for sure was a turn to a heading for a vector to the SFO localizer, I asked the controller to confirm this and he repeated the clearance but in the meantime the first officer was slowing the rate of descent and reducing air speed since he felt the latest clearance cancelled any previous restrictions that may have applied

at CEDES. When we had the controller repeat the clearance and confirm it he said we were cleared to leave CEDES on an assigned heading at 11,000. By now we are very close to CEDES just leaving 12,000 and slowing from about 290 KTS to 250 KTS. I told the first officer to get down to 11,000⁺ immediately and then slow to 250 KTS. He was under the impression that our crossing altitude at CEDES was no longer a restriction. We crossed CEDES between 11,000⁺ and 12,000⁺ and slowed to 250KTS within a few miles after passing the intersection. There were no subsequent communication difficulties. The thing that touched off the whole episode was the difficulty in reading the controller when he gave us the clearance to URN to an assigned heading when we were approaching CEDES. There was nothing wrong with our airplane receivers. The controller sounded as though he was not enunciating his words clearly but rather was slurring them together and trying to speak too rapidly. When he slowed up his delivery a little and spoke more clearly neither the first officer or I had any problem in understanding him.

ANALYSIS

The result of this misunderstanding led to no dire incident. It does point out, however, the absolute necessity of verifying and acknowledging all clearances.

ITEM 17

ACCESSION NO.

:2117

NARRATIVE

Prior to departure from Hotsprings (HOT), Arkansas, airline flight received IFR clearance for Hot Tower, ... V-54N maintain 5000, contact LittleRock (LIT) approach control at Benton intersection. First officer read clearance back to tower as issued. Flight crew misread clearance and proceed as cleared (and as filed) to 7000 instead of 5000. (7000 is FAL center stored flight plan). The error was not discovered until flight reported over Benton intersection. If an altitude verification had been required prior to Benton intersection, the incident could have been avoided, as it was however, flight flew one half of the flight segment without being required to verify the assigned altitude of 5000. Flight monitored Hot Tower Frequency until Benton intersection.

ANALYSIS

The reporters suggestion to always verify clearances is valid. It points out the vital necessity for a complete crew concept.

CALLBACK/COMMENTS

This is an example of what can happen when there is a change from S.O.P. Although the F/O received the altered altitude of 5000† the crew had been so accustomed to flying the center stored altitude of 700 that the change didn†t register mentally.

REPORTER'S RECOMMENDATIONS

I respectfully recommend that altitude verification be made to Hot Tower immediately after takeoff. I might add that Hot has no departure control as such.

ACCESSION NO. :2137

NARRATIVE

After landing on 2MR which is one of the south runways, I taxied north toward the terminal building, which is north of Runway 26. The normal route was not used, due to about 1500 FT of Runway 33 being closed. (Runway 33 is the normal taxi route) I mention that this information was not given to me by ground control or NTAMS or ATIS. This did not contribute directly to the incident, but indirectly, on arrival on Taxiway C, paralleling Runway 33 and holding short of Runway 26. I was Number 3 to cross Runway 26. However, there was another airline ACFT B outbound on Taxiway C on the north side of 26 which helped to create the problem. After sitting for a couple of minutes, ground control cleared ACFT B across Runway 26, but used the wrong trip number twice and also the pilot missed one transmission. By the time this was straightened out, it was too late for anyone to cross, due to departures off 26. After a couple more minutes, this trip was cleared across and I was Number 2 to cross. There had been several transmissions during this time that were broken or garbled and the outbound traffic was getting impatient about how they were going to get by the

inbound traffic. After more waiting, there was a break in departures and they cleared two or three more trips across Runway 26 which I thought I was one. The first officer tried to confirm this, but got no reply from ground control, which I took as another indication that we were already cleared. After crossing the runway and being almost to the gate, ground control asked if 660 was across the runway and the F/O replied, we were. Ground control comments was good luck. I feel the cause of this incident (which happens very frequently here in Atlanta) is the fact that under normal conditions at busy times of the day, ground control frequencies are overloaded and jammed and handling more traffic than one man on one frequency can control and when taxi routes are closed it compounds the problem.

ANALYSIS

If the allegations are true, the ground control situation at the ATL is pretty bad. The problem must also be obvious to the operating personnel.

REPORTER'S RECOMMENDATIONS

Traffic control of taxing aircraft on high density airports need some other type of communication other than radio due to mixing trip numbers. Blocked transmission and blank spots on airports. There were no near misses or any other type of hazard in this crossing. However, Atlanta has had some near misses by unauthorized crossing at other times.

ITEM 32

ACCESSION NO.

:2505

NARRATIVE

Enroute from SHV, to DFW, cruising altitude, 16000 FT - on the scurry four arrival (STAR), into DFW, we were given a descent to 6000 FT. in the area of GLADD intersection we were slowing at 10,000 and the controller asked us our altitude. I replied 10,000 (the first officer was flying the aircraft.) The controller replied - climb and maintain 11,000 - you are supposed to be at eleven. We immediately climbed to 11,000. (The visibility was good and as far as I know there was no traffic conflict.) I then told him I thought we were cleared to 6000 FT. He said he cleared us to maintain 11,000 to the laned intersection and then to descent to 6000. He further stated that I read it back to him that way. Background: we were almost an hour late out of SHV due to a mechanical. At the time of the descent clearance I was conferring with the FLT. Attendent on close passenger connections at DFW. (I was operating the radio. The F/O was flying the aircraft, there was no S/O). There was several items in the descent clearance - descent altitude, altimeter setting, and O.K. to disregard the speed restrictions and probably a couple of other things. If the controller did clear us as he stated, then I believe the situation occurred for three reasons. 1. I misunderstood the clearance or it did not register in my mind (The F/O missed it also). 2. the distractions in the cockpit by the

FLT attendant (not her fault). 3. The common practice of giving rapidly read descent clearances with several items in it.

REPORTER'S RECOMMENDATIONS

On two crew member aircraft - 1. Sterile cockpit (no extraneous conversation by FLT attendants, jump seat riders, or even among pilots themselves). A. During reading of any checklist. B. Descent to after landing. 2. When altitude change is given by controller that should be the only item in that transmission it should be read back by pilot and then other items transmitted. Comment: Many times when a descent clearance is rapidly given with several items in it. The crew member parrots it back and then tries to digest it in his mind. With complicated clearances there is always the possibility of missing or confusing part of it, especially if the pilot is unfamiliar with airport/area/approval.

ACCESSION NO. :2536

NARRATIVE

The captain was flying, myself copilot copies change of clearance from 179.1 LLM ARD to direct HAW ARZ after copying clearance I looked at the captain and though he indicated he got the new clearance as he changed the VOR FREQ from LLM to HAW. But due to the high he kept what appeared to be me to be a wind correction. Unknown to me he was proceeding to LLM. Just about LLM the center questioned our route of flight, then immediately changed our clearance back to LLM-ARL. No evasive action required.

ANALYSIS

An assumption on the co-pilots part that could have led to serious consequences had other traffic been involved. An example of what can result when all clearances are not verified by all crew members.

REPORTER'S RECOMMENDATIONS

Further development of windshield or whatever causes high noise level in cockpit of this airline ACFT type.

ITEM 41

ACCESSION NO. :2933

NARRATIVE

On the ground at PAX the F.O. called for ATC clearance to sea, clearance was field-maintain 9000 - expect FLY level 200 3 min. After departure, departure freq. and transponder code was also given. I missed the first portion of the clearance and picked it up at F.L. 200 (the center stored ALT) and got the freq. and transponder code, I set 20000 in the ALT. Alert unit and set in the transponder code as the F.O. read back the clearance. Again I did not hear the 9000 restriction and asked if we were cleared as field - the F.O. answered yes, I thought I understood the entire clearance. The F.O. made the takeoff and I changed to DEPT. control and reported leaving 1000 FT and climbing to F.L. 200 The controller said ~~ROGER~~ and gave us additional climb instructions which included a heading change at 2500 FTAT about 8000 FT the F.O. asked if we had been cleared to 20000 and I

replied, Yes - at 10000 FT. The controller asked what ALT. we had been cleared to and again I replied 2000. He said we should have been stopped at 9000 then cleared us to F.O. 200 and asked us to expedite thru 11000 which we did. The F.O. later said we had been cleared to 9000 originally, but thought we had been recleared to FL 200 and he had missed the re-clearance. The crew composition helped create this situation as the F/O regularly flew this trip, the CAPT. was a management pilot who hadn't flown the route recently and the S/O was a reserve who was totally unfamiliar with the route. The F/O on taxi-in at PDX, unknown to the CAPT. had set 9000 FT in ALT. ALERT SYS. in anticipation of what he knew was a normally ALT. restriction for departure, when the CAPT. thought he was given F.L. 200 with the clearance he set in that altitude replacing the 9000 FT - this was missed also by the F.O. and he read back the clearance and was not rechecked for a proper setting prior to takeoff. The CAPT. checked in with departure control after takeoff and stated he was climbing to F.L. 200 and received no correction. When the F.O. asked if we had been cleared to 200 FT and got a positive answer he assumed he had missed something and continued to climb thru 9000 FT.

ANALYSIS

He is putting out another reminder to his pilots to double check clearances.

REPORTER'S RECOMMENDATIONS

I will attempt to prevent a recurrence of this type situation by discussing the entire clearance with the crew and requesting ALT. verification when I change controllers during climb and descent. I will also discourage the presetting of instruments until after the clearance has been received and reviewed and I will encourage the other crew members to be more inquisitive when basic altitudes or rote changes occur.

ITEM 48

ACCESSION NO. :3077

NARRATIVE

While being vectored for an approach and landing on RW 22R approach, the following took place. Approach control when queried as to other traffic stated that we were his only IFR traffic but numerous others were arriving from other sectors and that he was working on a slot for us. The potential problem arose as the controller turned and descended us from a close high right downwind leg (040 DEG. HDG) to a 080 DEG heading while calling out the position of the traffic we were to follow on final, the captain mistook the heading to be 180 DEG as this was a logical heading to intercept final as the downwind was somewhat tight to the runway, I acknowledged the 080 DEG heading and looked out the window for the 1:00 o'clock traffic at 3 miles. The only traffic I saw appeared at 2:00 to 2:30 and looked to be 5 or 6 miles. I asked the controller if this was our

traffic and he replied with ~~what's~~[↑] your heading~~↓~~ I looked back into the cockpit to discover we were turning thru 170 DEG and said to the captain that we should be heading 080 DEG. I told the controller we were 170 DEG correcting back to the assigned. At this point the captain and I saw our traffic at 11:00 o'clock 2 1/2 to 3 miles. The controller said the heading should be easterly. I then acknowledged the traffic and we were then cleared for a visual approach. We made a left turn and one ~~S~~^{TURN} to position ourselves behind the traffic and proceeded without further confusion to the airport and landed. The conditions here in marginal VFR weather could be a setup for a near miss or midair. Fortunately, we were in clear air. Pilots and controllers anticipating visual approaches to expedite arrivals, save fuel and in general ease the burdens of day to day air operations could enter into this type of potentially hazardous situations. Hopefully this contribution can be of assistance in developing procedures and techniques for smoother and safer transitions.

ANALYSIS

A matter of misunderstood communications and an admitted pilot error.

ITEM 54

ACCESSION NO.

:3267

NARRATIVE

During CAPT↑S P/A talk to PSG↑S we received a change of HDS and change of ALT. from 9000 to 14000+ CAPT started climb and changed power while talking. When I finished talking F/O said left to 160 DEG I turned A/O and kept climbing - 16000 was in ALT reminder window. Levelled off at 16000 FT. called OPTR CTL and requested higher. Was advised we should be on CTR control. Called center, he asked if this was our first call, said yes, he asked for ALT, said 16000. He said we should be at 14000 but climb to FL230. We did we don't know who put 16000 in window of ALT reminder, we could not recall any conversation about changing to center. No. 1 radio still on DPT/CTL No. 2 on TWR at ATL, Man on DPT CTL did not seem to recognize us when we talked to him.

REPORTER↑S RECOMMENDATIONS

Personal cockpit procedures now incorporate a definite change of control when the man currently flying makes a P/A announcement. Hope to avoid future misunderstandings.

ITEM 55

ACCESSION NO.

:3272

NARRATIVE

On T/O we were told to turn RT on top 7000 FT. I started to him RT and CO. pilot said no he read back left turn.

Because for years we have turned left on thist/O I took co-pilot word instead of clarifying with DEPT. control. He stopped my turn at 270 DEG. and advised me the landings were on 8 and we were turning into traffic. We did not come close to any other ACFT and he climbed us up our landing traffic and continued left turn to our course.

REPORTER'S RECOMMENDATIONS

I, as Capt, should have clarified, the turn when the disagreement in conflict occurred.

ITEM 57

ACCESSION NO. :3318

NARRATIVE

We were inbound to MEM from the NO., on a downwind, west of the airport, 35L and right were active. Visibiltiy was 6 to 7 in haze. We were cleared for the visual to 35L with an altitude restriction to maintain 3000 FT. We maneuvered for the approach but couldn't get a lower because ACFT B was on approach for 35R at 2000 FT, and we didn't have visual contact with this ACFT. By the time we saw the other ACFT and could be cleared out of 3000, we were well above profile and behind on the check list and crew duties. In the rush, approach control either didn't turn us over to Tower or we failed to respond to his instructions, in any event the landing was made without a proper landing clearance. Separation between the two ACFT was positive at all times and was never compromised. The only problem was that the

visual search for the other ACFT and the delay in descent created an unusually heavy work load on the crew.

ANALYSIS

Appears to be a communication problem confounded with the requirement to look out for other ACFT. If approach control had furnished proper vectors for spacing the pilots work load would probably have been more normal.

ITEM 61

ACCESSION NO. :4087

NARRATIVE

At lift off on RWY 8R our forward entry door warning LGT came on. A decision was made to return and land. APC vectored us for a base TORWY 17L and CLRD us for a visual, to contact TWR on final. During this short period time, about 4 MINS the ck lists were run, LNDG gross WGT ok'd and while I worked APPCH CTNROL the first officer was advising the CO. and MNTNC of our action. Turning base the first officer returned to APC and I switched to the P.A. to advise the passengers of the prop and our intentions. Turning finals there was a momentary distraction over \neq BUG SPEED \neq as called by first officer and what was indicated on my airspeed indicator. This was resolved and the APPCH made to a LNDG - without contacting DEN TWRI I believe the AMT of communication involved in such a short time, the fact that at one point each of us worked APC CTL while the other was attending to other contacts (plus the distraction at the

point a change to TWR wuldnormally be made) lead to this oversight on our part, probably froma subjective assumption the other had made the TWR contact. The situation probably would not have developed had one crew member stayed in contact with CTL during the whole APPCH and it of course brings up the need for constant vigilance against ~~assumptions~~.

ANALYSIS

It appears that the RPTR has made an excellent analysis of the situation. Distraction and certain MT of stree can lead to a neglect ofeven routine SOP procedures.

ITEM 62

ACCESSION NO. :4194

NARRATIVE

As CPTN I misinterprted the assigned FLT ALT as being 16000 MSL wherein we were assigned 14000 MSL. First officer had read back CLRNC correctly when rec'd from CDC RDD, however, we both neglected to setalt reminder (non ACCRAL SYS) to 14000. The ALT reminder was set at16000 (previous legs assigned ALT). When the ATC CLRCN was rec'd engins and misread the CLRNC to read 16000 FT MSL instead of 14000 MSL. on LCB out thru 154000 LAX CTR aksed us our indicated ALT, we replied passing thru 15400 for 16000. He then issued us 16000 as assigned ALT. It is normal procedure for our airline to reset the ALT reminder to 0 FT when either CLRD for APPCH, or cancelling IFR CLRNC. This obviously was not done, and was a factorin in this incident.

ANALYSIS

An admitted pilot error.

REPORTER'S RECOMMENDATIONS

I recommend the non flying pilot always read back ALT assignments, and the flying pilot always set the ALT reminder. This should help to prevent 4 dangerous incident like this from happing when the GRND, and the F/O is copying the initial ATC CLRCN, the CPTN should set the ALT reminder so both ACK.

ITEM 66

ACCESSION NO. :4887

NARRATIVE

Clearance was received by first officer for flight to cross 15 DM W of FRR at or below 23000 \uparrow . Flight attendant discussing cabin situation with captain. CAPT. believed 23000 restriction was for 10DME and crossed 15 DME at little less than 24000 \uparrow at approx 3500 \uparrow FPM rate of descent previous cockpit coordination had been good and correct discipline maintained. For some unknown reason F/O failed to question or mention rate of descent necessary to cross correct DME point at altitude requested. CAPT believing crossing was 5 MI further east did not change descent rate as previously planned to cross the 10 DME fix at or below 23000 \uparrow .

ANALYSIS

The reported has probably analyzed the cause of this incident correctly.

REPORTER'S RECOMMENDATIONS

Believe more attention to strict cockpit discipline and less distraction from cabin attendants during climbs and descents would minimize this type of incident. Current company procedures do attempt to preclude or eliminate these distractions. Stricter cockpit discipline is the answer to this one.

ITEM 70

ACCESSION NO. :5215

NARRATIVE

Pilot in command performed totally unnecessary and violet low altitude maneuver attempting to complete a close in visual approach, once the situation was underway the alternative for other flight crew members were either a fight for the controls at 500 FT or verbal suggestions and protests. In this case the latter was chosen. Aside from irresponsible and reckless individuals who must be dealt with, this situation once again points up the need for early and forceful crewmember input to the pilot to prevent condition from deteriorating to the point of crisis. Without this input, even a conscientious pilot (perhaps not perceiving a critical factor) might then try to complete an approach which should be abandoned.

ANALYSIS

It is strictly a matter between the reporter and his airline flightmanager.

ITEM 74

CCESSION NO.

:5381

NARRATIVE

Myself and the rest of crew deadheaded from MTS to PIT on Flight 204 and proceeded to Gate 16 where outbound equipment for Flight 231 was scheduled for departure at approximately 1340E. We found Flight 287 still on gate. Maintenance informed us our aircraft was still at the hanger and would be parked on Gate 16. We left our bags and proceeded to operations. In operations we checked TV monitor which indicated Gate 16 aircraft still at hanger. I proceeded in completing of flight plan which indicated PIT to SDF fuel load 22,000 LBS. CAPTAINWHELCHER and myself discussed enroute weather or thunderstorm lines etc, periodically checking TV monitor. At approximately 1355E (1755Z) the TV monitor still indicated aircraft at hanger but decided to proceed gate anyway. Captain and myself arrived at Gate 16 at approximately 1400E (1P00Z) and found aircraft at the gate. I performed walk around inspection while Captain boarded the aircraft. When I boarded the aircraft I found fuel slip for 24,600 LBS in area of radar scope and placed it on my side assuming that extra fuel was added because of weather enroute. I proceeded to read check list to Captain and at fuel, oil, hydraulic quantities checked fuel slip and informed Captain I had fuel slip and completed check list. We were ready for push back at 1410E (1810Z)

on schedule and contacted ground control, also during, push back I was receiving ATC clearance. After completing after start check list proceeded to Runway 28R. Completing before take off checklist. At this time I added an additional 2600 LBS offuel to take off weight and gave corrected take off weight. Since it was my leg to fly, I performed normal take-off at 1416E (1816Z) and climb out. At approximately 15,000 FT I changed to center tank andnoticed no fuel in center. I immediately looked at fuel slip, sinceI knew fuel should be in center tank and informed Captain that no fuel was in center tank, who by this time was looking at fuel quantities also. Captain said ~~≠SOMETHING CRAZY HERE≠~~ We leveled off at approximately FL210 and I pulled pwr back while we were determining the problem. After discussing the matter, we decided we had to go withthe present indication of fuel and decided CMH as being our best place for landing to have checked. We contacted systems control and received amended release to CMH at 1427E (182777) 11 minutes after take off, at this time, during descent into CMH we informed flight attendants of the problem and that we were landing at CMH, also informedpassengers of problem on PA. Proceeded to CMH with normal landing at 1447E (18477) and taxied to gate. At the gate, we had dip sticks and all guages checked and found fuel to agree with indications. We had aircraft fueled and informed passengers that the problem had been corrected and we were taking on additional fuel as a

precuation andfor weather. We then proceeded to SDF with everything normal.

ANALYSIS

Pilots assumed a fuel slip in the cockpit was the proper slip for their flight. Fuel handler smudged flight number. Refueling personnel notified company, during pushback, that flight was not refueled. Compnay failed to notify pilots. The gate coordinator in the Tower forgot about it. When pilot checked fuel totalizer gage it read.

ITEM 10

ACCESSION NO. :5680

NARRATIVE

When the original clearance was received RWY 5 was in use. The clearance was a TULANCLINGO DEPT. (Via ME TCG). Upon departing terminal the active Runway has changed to RWY 23. After takeoff on RWY 23R, departure control's clearance was to proceed to MW then turn right to heading 340 DEG. The co-pilot was flying the aircraft and apparently missed the clearance from departure control and started a left turn as per the TCG departure. Language problem contributed to the mis-understanding of the clearance. In the left turn I said to the co-pilot, ~~we were suppose to turn to the right~~ and he assuredme that the correct turn was to the left. As we were in the left turn, departure control came on and advised us that we were cleared for a rightturn. I explained that we had mis-understood the clearance and thatwe were proceeding to ME for ATCG departure. Departure control thencleared us to

ME and a change of frequency, and at that time nothing more was said of the incident. In retrospect, better cockpit discipline would have prevented this incident.

ANALYSIS

Both captain and F-O apparently didn't register the clearance. F-O didn't seem to hear the clearance and talked the captain out of what the captain thought was a new clearance with a right turn. Crew could have been inattentive, or cockpit noise and workload during takeoff climb make that period a difficult time to receive clearances.

CALLBACK/COMMENTS : NONE

REPORTER'S RECOMMENDATIONS : NONE

ITEM 81

ACCESSION NO. : 5699

NARRATIVE

ATC told us to expect 250 KT 10000' restriction at saddle intersection, but didn't give us a clearance to descent. I repeat the clearance to the controller and asked the copilot who was flying it he understood. He said yes. ATC kept us 33000 longer than normal and did not tell us they had traffic at 31000. We were well past normal descent point and I turned to get something out of my flight bag. While I was looking for the object the co-pilot started a descent without my knowledge. The altitude alerter went off and the co-pilot reset it to 10000. I did not hear the Alerter go off, ATC asked if we were descending, I looked at

he altitude and we were at 31700 DEG., I immediately told the co-pilot to climb and told ATC that we had left our altitude by mistake. He (ATC) then cleared us to 10000 and said we had traffic at 31000. The co-pilot had about 4 months as co-pilot. I think he became nervous that he was so high and turned the expected clearance in his mind to an actual clearance.

ANALYSIS

Copilot incorrectly began descent before being cleared. Captain may have point that a restriction mentioning speed and altitude might better be given after clearance to descend, there's less chance for misinterpretation.

CALLBACK/COMMENTS : NONE

REPORTER'S RECOMMENDATIONS

I don't think the incident would have happened if ATC had not given the expected restrictions until after they had given us clearance to descend.

ITEM 82

ACCESSION NO. :5720

NARRATIVE

LT cleared to 6000' co-pilot was operating controls, captain was looking in his book of approach plates. Co pilot was turning ADF NAV AID to 344 AVN AVON outer marker locator. Aircraft was at 10000' slowing from 350 KTS to 250 KTS. with attention diverted to tuning and identifying OM locator, aircraft descended to 9400' at 300 KTS.

ANALYSIS

Both pilots distracted, allowed aircraft to descend above max speed, pilot error.

CALLBACK/COMMENTS : NONE

REPORTER'S RECOMMENDATIONS : NONE

ITEM 83

ACCESSION NO: :5740

NARRATIVE

Our aircraft arrived on OMA I went into the operations office to check WX use the restroom. On returning to the aircraft I asked the F.O. if we had an ATC clearance. He replied that we did I asked him what it was. He said ~~✓~~CLEARED AS FILED MAINTAIN 5000 EXPECT 11000 10 MIN AFTER DEPARTURE.~~✓~~ Our flight plans are all center storred and I asked him ~~✓~~How are we filed~~✓~~ to verify the routing I had on mycenter storred flight plan his, as filed, was the same as my as filed, namely V159 STJ direct MCI. The departure went normally We were handed off to center (Minneapolis) As I flew the ACFT on the previos routing to 11000~~+~~, we crossed OMA VOR proceeded on course V159. Approx 25 N.W. SE of OMA VOR as we were being handed off to Kansas City center Minneapolis asked ~~✓~~Are you flying the Omaha 1 arrival~~✓~~ I answered that we weren't that it was my understanding we were cleared V159. He said that we weren't but that we could work it out with Kansas City. Handoff was detected Kansas City turned us to 165DEG Vectored us the

approach gate at Kansas City. I again asked the F/O for the clearance that he copied. He said that it was his mistake that he did not know what Omaha 1 arrival meant that he checked my approach rates. HIS Neither of us had a Omaha S.I.D. by that name so he ignored it but read the clearance back ~~≠~~KANSAS CITY ASFILED MAINTAIN 5000, expect 11000 10 min. after departure. And that Omaha clearance delivery accepted the read back and that he did not think to ask me about Omaha One Arrival when I returned to the aircraft. I felt like I had been sold down the river by an otherwise very trustworthy, competent F/O. Clearly, he made a serious mistake as I suppose I did in not checking the clearance with clearance delivery, to do so however would surely leave your F.O with the feeling that ~~≠~~THIS GUY DOESN'T TRUST ME~~≠~~, which is now the case. But on the other hand trust coordination are definitely necessary for a safe operation. While crosscheck is a healthy worthwhile cockpit activity, it becomes counter productive when one crew member feels ~~≠~~I'm getting a check ride~~≠~~ from the other crew members. For this reason, I probably won't question the next clearance I get from this or any other F.O, but I'll be uneasy. The nagging fear that he may have miscopied or misunderstood will be in the back of my mind, many of our days require 14 hrs in the cockpit the physiological needs of crew members necessitate that all are not going to be present in the cockpit at all times.

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